MODELS OF THE SENIOR NAVAL OFFICER RANKS

by

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United States
Naval Postgraduate School

THESIS

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ABSTRACT

This thesis develops deterministic and stochastic models for comparison of attrition and promotion rates for senior Naval Officers. The deterministic models show a feasible region for promotion and attrition rates. The stochastic models show the probability distribution of inputs into the grade and retirements from the grade which result from a promotion system based on a minimum time in rank and a promotion system where the number of promotions are determined independently of the number in rank.

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I. INTRODUCTION

The officer personnel system currently in existence in the Navy is an outgrowth of many years of development, legislative action and service policy. When viewed as a system the management of officer personnel in the Navy is subject to numerous constraints at various levels such as overall size and budget, while at the same time it has no mathematical objective function. The general objective of the officer personnel system is to provide a means of selecting, promoting and separating officers in the most efficient manner in order to provide at all times a vital officer corps of sufficient quality and quantity to meet service needs.

Effective manpower management requires top management of the organization to have knowledge of or be able to reasonably predict changes in the organization and be able to interpret how those changes will effect the organization. In particular, if a change in promotion policy is contemplated, what effect will the policy have on the people below the promotion point, the number of people remaining in the organization and the people already promoted to the level of change. Many questions both analytical and psychological must be entertained and resolved by personnel managers.

This paper develops deterministic and probabilistic models which relate attrition rate to promotion rate for senior Naval Officers. We present data to show that at these ranks officers leave a rank essentially by promotion or retirement only. The

models we formulate use this fact and hence are not intended to model the behavior of junior rank officers where attrition occurs in many ways other than retirement or promotion.

A. OFFICER PERSONNEL

The Navy officer corps is categorized by unrestricted line, restricted line, staff corps, and limited duty officers. The unrestricted line category of officers perform the general tasks of conducting naval warfare, while the restricted line catagory provides technical guidance in specialized areas of naval warfare. Staff corps personnel provide support to naval warfare units in the form of medical services, supply, legal, and civil and naval engineering facilities. The limited duty officers are commissioned from the enlisted ranks and perform the same functions as the unrestricted line officer but are not eligible to command major naval units.

1. Grade Size

The Officer Personnel Act of 1947 [Ref 2] and the Officer Grade Limitation Act of 1954 [Ref 3] introduced constraints on the number of officers authorized within certain grades. The number of unrestricted line officers within each grade is a function of the total number of unrestricted line officers on active duty. The constraints for three grades are:

URL STRENGTH	CAPTAIN	COMMANDER	LIEUTENANT COMMANDER
32,000	6.0%	12.0%	18.0%
40,000	5.8	11.2	17.5
50,000	5.5	10.5	17.3
60,000	5.2	9.8	16.9
70,000	5.0	9.1	16.4

The above combination of unrestricted line strength and percentage authorized establishes the "statutory ceiling" for the above grades.

In addition, the Secretary of the Navy can establish the strength within a particular grade at a lesser number of officers than the number derived by the above percentages and this number becomes the constraint within each grade. The number within each grade established by the Secretary of the Navy is often referred to as the "prescribed number" within each grade.

A similar set of "statutory ceilings" exists for the restricted line and limited duty officer catagories of officer personnel. The staff corps have no grade ceilings; instead, total corps ceilings are established as a percent of the unrestricted line strength.

2. Promotions

Promotions in the Navy officer corps are a function of many things. Two major factors considered in this paper are:

(a) the number of officers that the Secretary of the Navy prescribes to be maintained in each grade (usually less than the "statutory ceilings" and never more).

(b) the total commissioned service accured prior to becoming eligible for promotion.

The prescribed number by grade establishes the maximum number of officers in that grade. Thus, the number to

be promoted in a particular grade is a function of the prescribed number and the vacancies which currently exist in that grade, i.e., prescribed number less the actual number, plus the projected vacancies which will occur in the next twelve months.

In order to ensure adequate experience is maintained within each grade and in the Navy as a whole, and due to legal constraints of the TITLE 10, U.S. CODE, the promotion system is based on a minimum number of years in each grade and hence a minimum total commissioned service prior to becoming eligible for promotion.

To maintain quality control of personnel, not all officers eligible for promotion are selected to the next higher grade. In the grades of Ensign through Lieutenant, those officers twice failing to be selected to the next higher grade are separated from the Navy. In the grade of Lieutenant Commander through Captain, a minimum of 20, 26, and 30 years, respectively, of active duty is authorized by TITLE 10, U.S. CODE, without regard to failure of selection to the next higher grade. Thus, the ranks of Lieutenant Commander through Captain are guaranteed a statutory retirement.

3. Inputs Into the System

The main source of Regular officers entering the Navy is the U.S. Naval Academy and Regular NROTC program. However, in terms of size the largest input into the Naval officer personnel system is from the Officer Candidate School (OCS).

All officers entering the system via OCS are Reserve officers with a contractual agreement to remain in the Navy a specific length of time. Transfer from the Reserve status to Regular status is controlled by application and selection board procedure.

Since the total size of the officer corps is constrained by budgetary considerations, which vary from year to year, and the inflexibility of instantaneously increasing the entrants into the system from the Naval Academy and Regular NROTC, the inputs into the system from the OCS program are used as a control valve for maintaining the total size of the officer corps within the required constraints.

4. System Losses

Attrition from the system can occur in any one of the following ways:

(a) resignation of commission
(b) retirement
(c) disciplinary discharge
(d) death
(e) disability discharge
(f) promotion failure
(g) release from active duty
(h) reversion to enlisted status (LDO only)

Table I developed by Klingerman [Ref 1] shows the relative size of attrition losses by rank for the Marine Corps in a ten year period. It may be noted from Table I that in the three senior ranks of the Marine Corps more than 70% of those leaving by other than promotion do so by retirement, while in the two senior ranks retirements account for more than 94% of the losses exclusive of promotion losses.

CATAGORY	COL	LtCOL	MAJ	RANK CAPT	1stLT	2ndLT	Total
Released	8	42	160	3130	7169	18	10,527
Retired	851	1360	1571	804	209	56	4,851
Resigned	0	2	152	1537	1097	280	3,104
Died	21	45	111	277	355	324	1,133
Discharged	0	1	19	272	133	180	605
Reverted	0	0	0	16	161	10	187
Total	880	1450	2013	6072	9124	868	20,407

TABLE I: MARINE CORPS OFFICER LOSSES BY CATAGORY BY RANK

The Discharged catagory in Table I includes discharges for both disciplinary reasons and disabilities. It is felt that similar proportions to those in this table would occur in the Navy, but data was not available to check this.

In the ranks of Ensign through Lieutenant the system is influenced by many factors external to the system such as economic conditions and budgetary constraints, in that personnel can be removed from the system for the convenience of the government and desires of the individual. In addition, these ranks are terminal in a two year period if the individual is not promoted to the next higher rank. In modeling the ranks of Ensign through Lieutenant these numerous types of system losses must be taken into account and any analysis must therefore be complex. Only the ranks of Lieutenant Commander through Captain will be considered in this paper and from Table I we shall assume that all losses from these ranks are by either promotion or retirement.

In these models no attempt is made to distinguish between the four designation catagories of officers or between Regular and Reserve officers.

II. DETERMINISTIC MODELS

If the number of inputs (m), promotions (p), and retirements (m-p), are considered deterministic and the rank size (N) is constant then given any two of the parameters (m, p, or N) the third can be calculated.

Let us assume:

1. Promotions occur simultaneously at the end of year t (or the start of year t+1).

2. All persons not promoted remain in the system the maximum amount of time allowable until mandatory retirement at year n.

3. Only losses due to promotions and retirements occur.

4. The rank size is constant over time.

5. All entrants to the system enter at the start of year 1.

Let:

N = number of officers in rank

n = number of years in rank if not promoted

t = number of years in rank if promoted

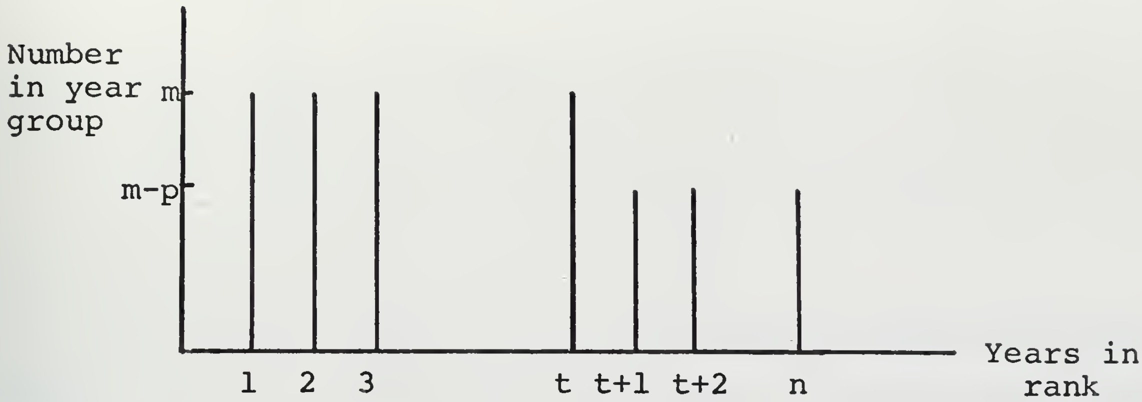
m = new inputs into the rank per year

p = number promoted to the next higher rank per year

α = the fraction of the total number of people in rank which are promoted per unit of time (total fractional promotion rate) (p/N)

ϕ = fractional loss rate (number of people lost to the system by other than promotion per unit time per number of people in rank)

A particular rank could be viewed as the following:



The total number in grade is:

$$tm + (n-t)(m-p) = N. \qquad 1.0$$

Then

$$m = \frac{N + p(n-t)}{n},$$

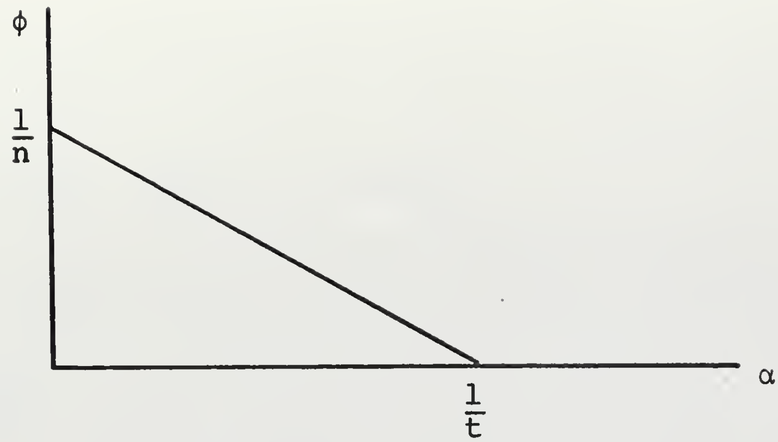
since

$$\phi = \frac{m-p}{N},$$

then

$$\phi = \frac{1}{n} - \alpha \frac{t}{n}. \qquad 1.1$$

The fractional loss rate is a linear function of the fractional promotion rate, as shown below:



Equation 1.1 implies that the maximum value of the promotion rate is a function of the number of years until promotion, while the maximum loss rate is proportional to the number of years until retirement. If the system were such that $t = n$, i.e., that promotion and retirement occurred simultaneously, then the slope of 1.1 will decrease to the point where a change in the promotion rate will result in an equal change in the loss rate.

Now consider the same system with retirements permitted each year at a given number per year, if failure to be promoted has occurred, i.e., retirements are permitted only from those not promoted.

Let:

L = number of losses due to retirement per year, from $t + 1$ to year n, i.e., the earliest retirement cannot occur until the start of year $t + 1$.

Then the total number in rank is:

$$tm + (m-p)(n-t) - [n - (t+1)]\,L = N \,. \qquad 1.2$$

Then

$$m = \frac{N + [n - (t+1)]L + p(n-t)}{n} .$$

Since

$$\phi = \frac{m-p}{N} ,$$

$$\phi = \frac{1}{n} + \frac{L[n - (t+1)]}{nN} - \alpha \frac{t}{n} . \qquad 1.3$$

Since the system size is constant the total retirement losses per year (L) cannot be greater than the number of inputs less losses due to promotion, thus:

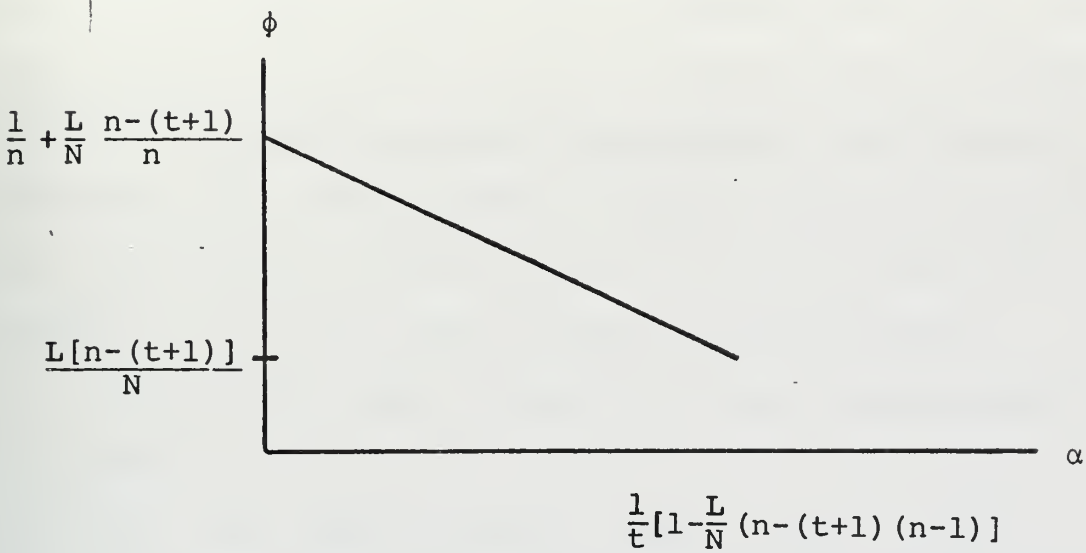
$$[n - (t+1)]L \leq m-p$$

$$\frac{[n - (t+1)]L}{N} \leq \phi . \qquad 1.4$$

Thus a lower bound on the loss rate can be established, at which the promotion rate is:

$$\alpha = \frac{1}{t}\left[1 - \frac{[n - (t+1)](n-1)L}{N} \right] . \qquad 1.5$$

Loss rate as a function of promotion rate is shown below.



The effect of early retirements (L) is to force a lower bound on the loss rate and an upper bound on the promotion rate. In addition, the upper bound on promotion rate establishes an upper bound on early retirements (since the promotion rate cannot be negative) as:

$$L \leq \frac{N}{[n - (t+1)](n-1)} \quad .$$

If early retirements assume the upper bound the promotion rate decreases to zero and the system degenerates into one in which all inputs leave only by retirement. As early retirments approach zero the system returns to the previous model.

Any combination of parameters within the above bounds will provide a feasible solution in that by specifying any four of the parameters the feasible area for ϕ and α can be determined.

III. STOCHASTIC MODELS

The number of promotions, retirements, and inputs each year in the actual system are not deterministic but vary from year to year as changes occur in service policy, economic conditions, promotion rates, and numerous other factors. Therefore, the actual number of people leaving or entering the grade can be characterized as the realization of a random variable (r.v.) from some probability distribution.

Consider the same assumptions as the deterministic model.

Let:

M_j = new inputs into the rank in year j (r.v.)

P_j = promotions from those eligible in year j (r.v.)

m_j = expected value of M_j

p_j = expected value of P_j

Assume stationary conditions so the $m_j = m$ and $p_j = p$ for all j.

The subscripts on M_j and P_j will be dropped when it is not necessary to specify any given year j.

δ = the fraction of the number of people eligible for promotion (with minimum time in rank) which are promoted per unit time (year group fractional promotion rate), i.e., expected number of people promoted per expected number of people at the promotion point.

$\delta = p/m$

Thus the inventory equation is:

$$\sum_{i=j-(n-1)}^{j} M_i - \sum_{i=j-(n-1)}^{j-t} P_i = N. \qquad 1.6$$

Taking expectations we have

$$nm - (n-t)\bar{p} = N.$$

Since $p = \delta m$, then

$$nm - (n-t)\delta m = N,$$

$$m = \frac{N}{n(1-\delta) + \delta t} \qquad 1.7$$

Equation 1.7 gives the mean of M_j in terms of the promotion rate. The question arises as to what is the distribution of M_j for a given promotion policy?

M_j is a discrete valued random variable in the range 0 to N, with the mean given by equation 1.7. One conjecture is that M_j is binomially distributed with parameters N and $\frac{1}{n(1-\delta) + \delta t}$. However its distribution will probably depend on how promotions can occur. In the next sections we show that when promotions can occur only from the number with t years in grade the binomial conjecture seems to be valid. When P_j is determined independently of the distribution of officers in grade, so that early promotions can occur, then the binomial conjecture appears to be false.

A. MODEL WITH PROMOTIONS ONLY FROM THOSE WITH t YEARS IN GRADE

Assume that P_j, given M_{j-t}, is binomial with parameters M_{j-t} and δ. Then using the following parameter values, the

model was simulated in order to estimate the steady state distribution of M.

$N = 100$

$n = 10$

$t = 6$

$\delta = .5$

The resulting emperical distribution of inputs appeared to be binomial. A Chi Square Goodness of Fit Test was conducted with the emperical distribution and a binomial with parameters N, and $\frac{1}{n(1-\delta) + \delta t}$. The hypothesis was accepted at the .95 level as shown in Table II. Figure 1 shows the emperical distribution of inputs with the hypothesised distribution superimposed.

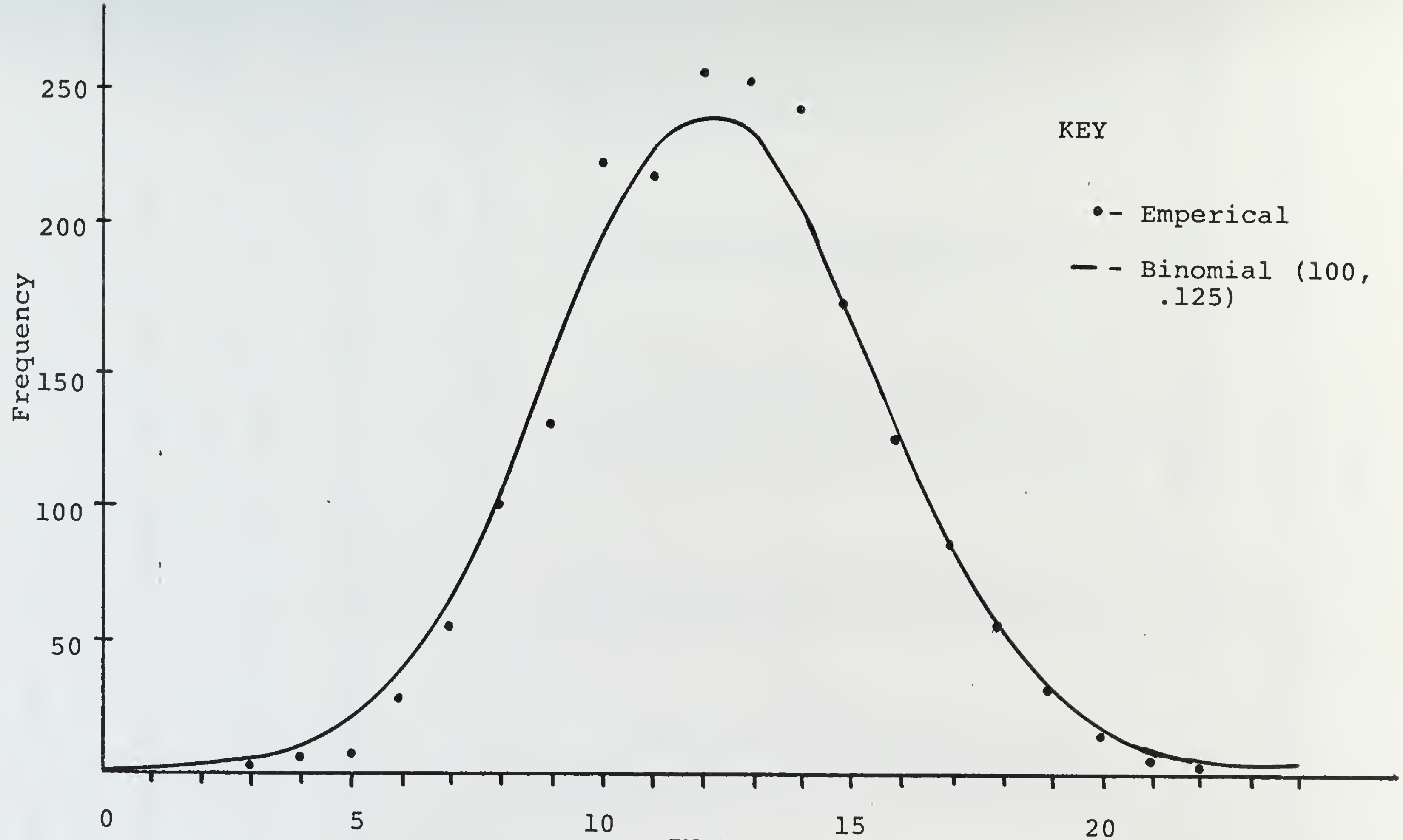


Figure 1. Frequency Distribution of Inputs When Promotion Occurs Only After t Years In Grade.

TABLE II

CHI SQUARE TEST FOR EMPERICAL DISTRIBUTION OF INPUTS WHEN PROMOTION OCCURS ONLY AFTER t YEARS IN GRADE

Number of Inputs	Observed Frequency (0)	Expected Frequency (E)	(0-E)	$(0-E)^2$	$(0-E)^2/E$
3-4	7	6.79	.31	.09	.00
5	6	14.28	8.28	68.56	4.80
6	25	32.28	7.28	53.00	1.64
7	53	61.73	8.73	76.21	1.23
8	100	102.61	2.61	6.81	.07
9	128	149.75	21.75	473.06	3.16
10	220	194.61	5.39	29.05	.15
11	217	227.56	10.56	110.25	.48
12	255	241.10	13.90	193.21	.80
13	250	233.16	16.84	282.20	1.21
14	239	206.90	32.10	1030.41	4.98
15	173	169.56	3.44	11.83	.07
16	123	128.61	5.61	31.47	.24
17	86	90.88	4.88	23.81	.26
18	56	59.80	3.80	14.40	.24
19	31	36.97	5.97	35.64	.96
20	17	21.43	4.43	19.62	.92
21	9	11.71	2.71	7.31	.62
22	5	5.96	.96	.92	.16
23-24	0	4.41	4.41	4.41	4.41
					26.40

Degrees of freedom = 18

χ^2 .95,18 = 28.9

B. MODEL WITH PROMOTIONS DETERMINED INDEPENDENT OF GRADE STRUCTURE

Assume that the number being promoted each year is a random variable chosen external to the rank being considered. Since in any given year the number to be promoted may exceed the number of people at the promotion point, promotion without sufficient time in grade is permitted. Early promotion is permitted in sufficient quantity to satisfy the external constraint.

The resulting emperical distribution of inputs with the hypothesised binomial distribution superimposed is shown in Figure 2. The conjecture that inputs are binomially distributed is clearly invalid in this model.

C. DISTRIBUTION OF RETIREMENTS AND PROMOTIONS FROM THE DIFFERENT PROMOTIONS POLICIES

In addition to providing estimates of the distribution of inputs, the simulation provided insight into the distribution of retirements and promotions.

Let:

R_j = retirements from the rank in year j

r_j = expected value of R_j

Assume stationary conditions so that $r_j = r$ for all j.

Retirements in any year are the number of inputs n years before less the number of promotions t years earlier, or

$$r = m(1-\delta)$$

$$r = \frac{N(1-\delta)}{n(1-\delta) + \delta t} \; . \qquad 1.8$$

Thus the mean of the retirements distribution can be estimated analytically.

Since retirement rate (number of retirements per year per number of people in rank) is

$$\frac{(1-\delta)}{n(1-\delta) + \delta t}$$

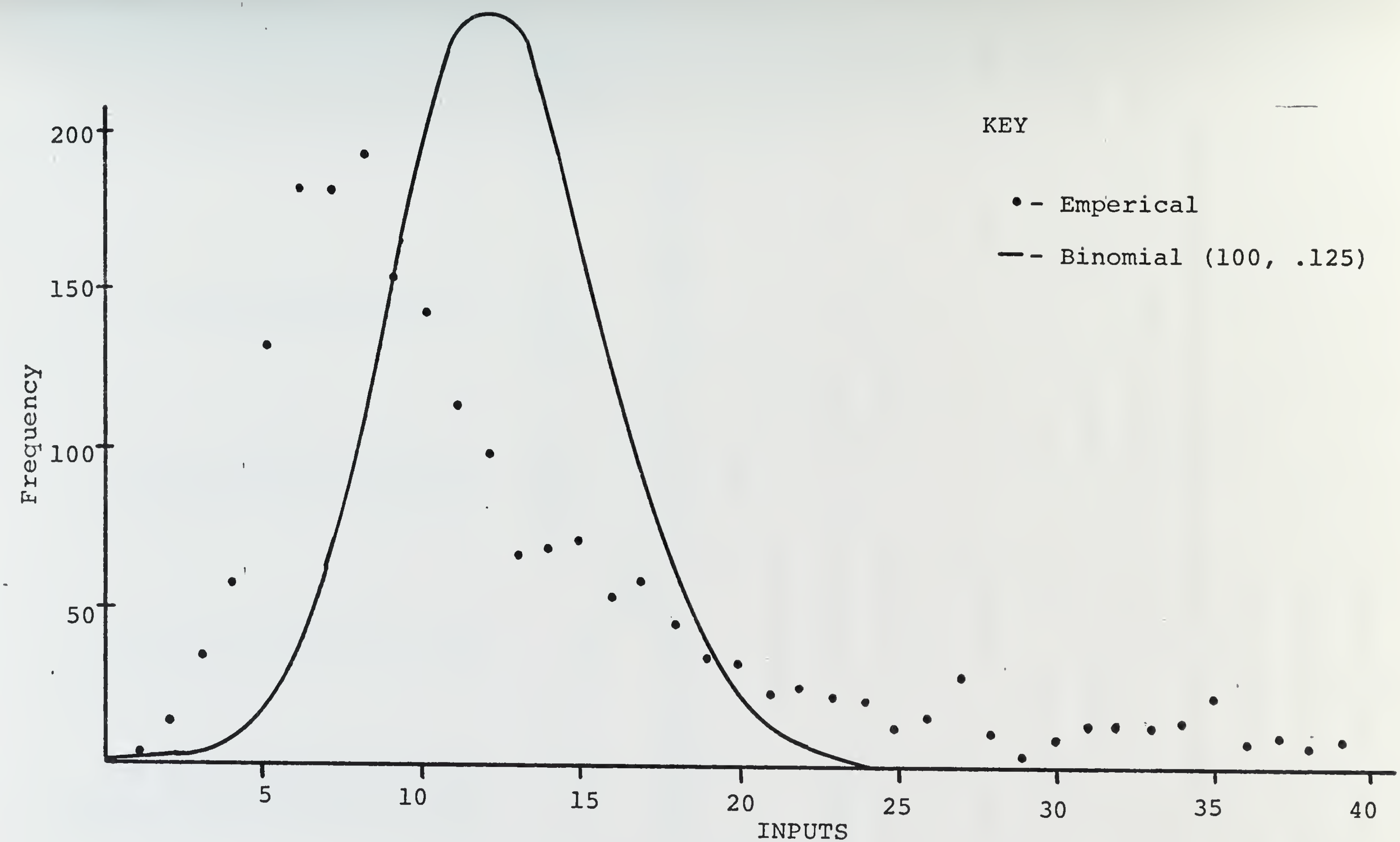


Figure 2. Frequency Distribution of Inputs When Promotions Are Independent of Grade Structure.

a confidence interval for the retirement rate given a promotion rate can be established. Figure 3 shows the retirement rate at various promotion rates with a 95% confidence interval.

From the emperical distribution of retirements generated by the model in which promotions occured only from those with t years in grade, it appeared that retirements were distributed Poisson with parameter r equal to 6.25. The hypothesis that the emperical distribution of retirements were distributed Poisson (6.25) was tested with a Chi Square Test as shown in Table III. The hypothesis was accepted at the .95 level. Figure 4 shows the emperical distribution of retirements with a Poisson (6.25) distribution superimposed.

TABLE III

CHI SQUARE TEST FOR EMPERICAL DISTRIBUTION OF RETIREMENTS WHEN PROMOTION OCCURS ONLY AFTER t YEARS IN GRADE

Number of Retirements	Observed Frequency (O)	Expected Frequency (E)	(O-E)	$(O-E)^2$	$(O-E)^2/E$
0	1	3.9	2.9	8.41	2.16
1	19	24.1	5.1	26.01	1.08
2	66	75.4	9.4	88.36	1.17
3	141	157.0	16.0	256.00	1.63
4	263	245.3	17.7	313.29	1.28
5	327	306.6	20.4	416.16	1.36
6	309	319.5	10.5	110.25	.35
7	306	285.3	20.7	428.49	1.50
8	235	222.8	12.2	148.84	.67
9	163	154.6	8.4	70.56	.46
10	85	99.6	14.6	213.16	2.14
11	48	54.9	6.9	47.61	.87
12	21	28.6	7.6	57.76	2.02
13	9	13.8	4.8	23.04	1.67
14	5	6.1	1.1	1.21	.20
15-16	2	2.5	.5	.25	.10
					18.66

Degrees of freedom = 14

$\chi^2_{.95,14} = 23.7$

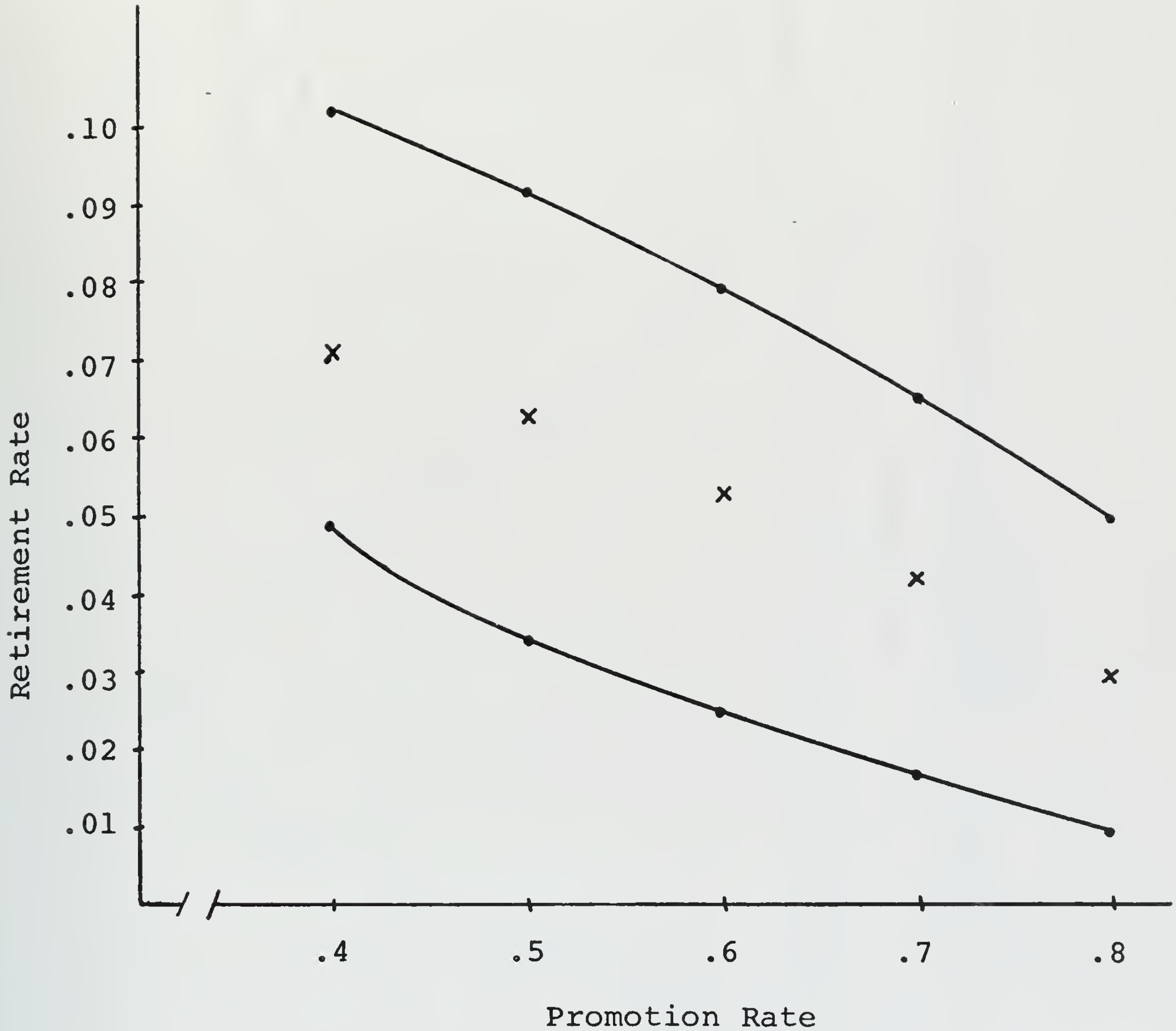


Figure 3. Promotion Rate vs Retirement Rate

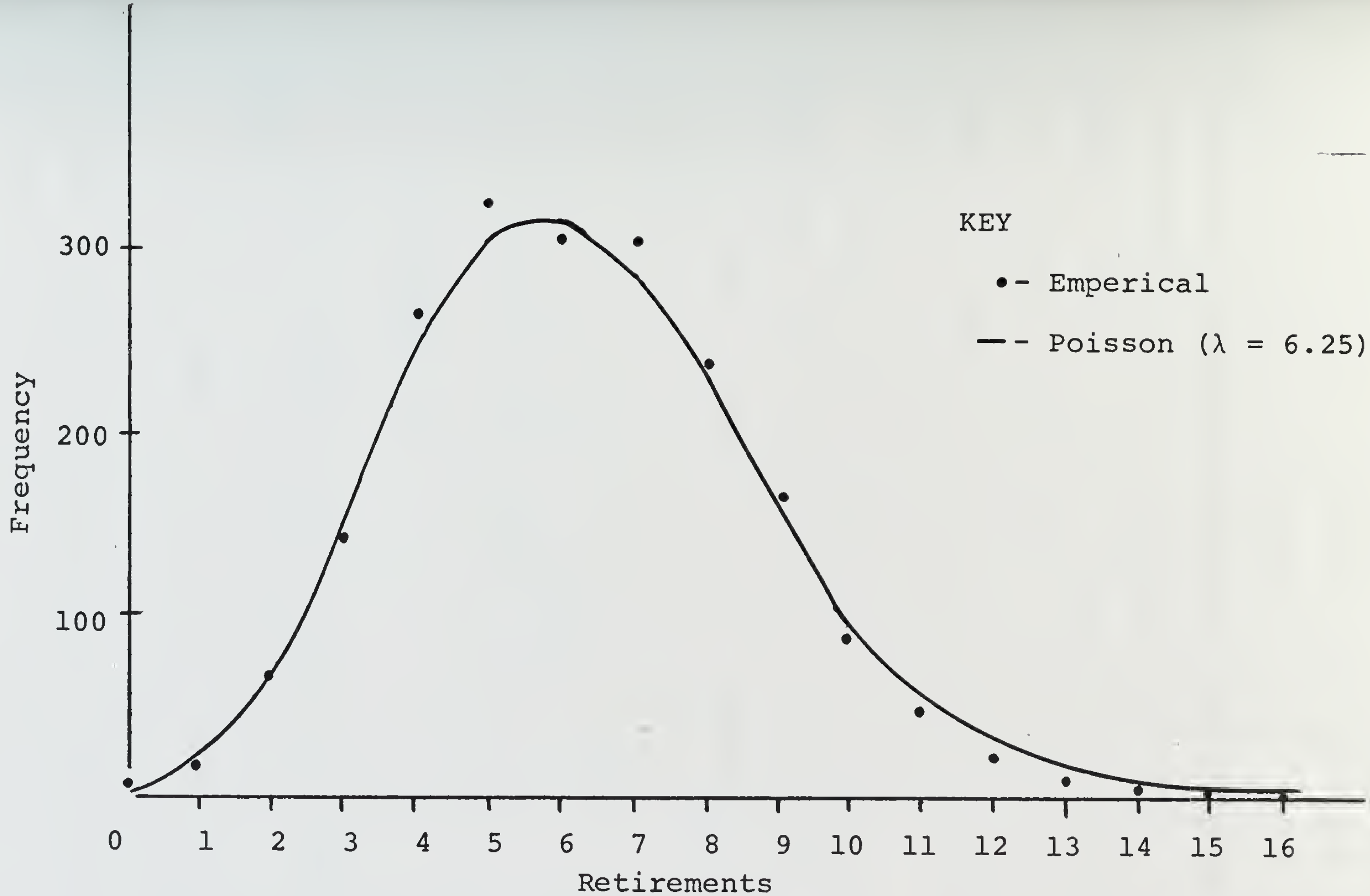


Figure 4. Frequency Distribution of Retirements When Promotions Occur Only After t Years In Grade.

The emperical distribution of retirements generated by the model in which promotions were generated indpendent of the grade structure is shown in Figure 5. The emperical distribution of retirements from this model clearly does not support the conjecture that retirements are Poisson distributed. However, Figure 5 shows a Geometric distribution with parameter p = .14 superimposed which, even though not passing a Chi square test appears to be a good approximation of the emperical retirements distributions from this model.

Assuming that the system is in steady state and flow in must equal flow out, the number of promotions per year is equal to the number of inputs less the number of retirements, or

$$p = m - r$$

$$p = \frac{N}{n(1-\delta) + \delta t} - \frac{N(1-\delta)}{n(1-\delta) + \delta t}$$

$$p = \frac{N\delta}{n(1-\delta) + \delta t} \quad . \qquad 1.9$$

Thus, the mean of the unconditional distribution of promotions can be estimated analytically.

From the emperical distribution of promotions generated by the model in which promotion is permitted only after $\underline{t}$ years in grade, promotions appeared to be distributed Poisson. The hypothesis that the emperical distribution of promotions was distributed Poisson with parameter p = 6.25 was tested with a Chi Square Test as shown in Table IV. The hypothesis was accepted at the .975 level. (Note: The hypothesis was

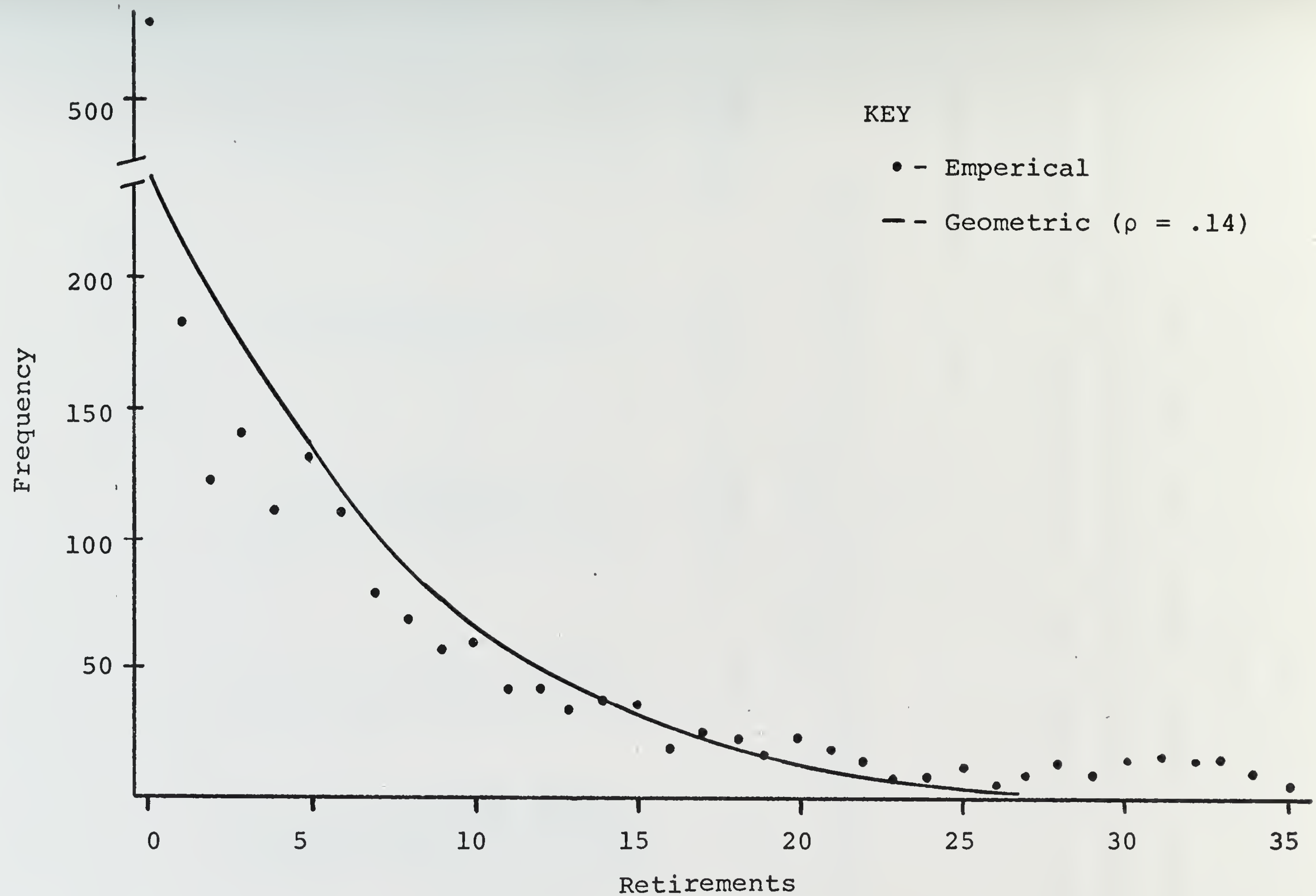


Figure 5. Frequency Distribution of Retirements When Promotions Are Independent of Grade Structure

rejected at the .95 level however, since the largest contribution to the computed Chi Square value was due to deviations of the tail of the emperical from the theoretical distribution, it was felt the theoretical Poisson was a good approximation of the emperical distribution.) The emperical distribution of promotions with a Poisson distribution of parameter 6.25 superimposed is shown in Figure 6.

TABLE IV

CHI SQUARE TEST FOR EMPERICAL DISTRIBUTION OF PROMOTIONS WHEN PROMOTION OCCURS ONLY AFTER t YEARS IN GRADE

Number of Promotions	Observed Frequency (O)	Expected Frequency (E)	(O-E)	$(O-E)^2$	$(O-E)^2/E$
0	5	3.9	1.1	1.21	.31
1	18	24.1	6.1	37.21	1.54
2	59	75.4	16.4	268.96	3.57
3	134	157.0	23.0	529.00	3.37
4	246	245.3	.7	.49	.00
5	311	306.6	4.5	319.36	.06
6	339	319.5	19.5	380.25	1.19
7	301	285.3	15.7	246.49	.86
8	253	222.8	30.2	912.04	4.09
9	155	154.6	.4	.16	.00
10	84	99.6	15.6	243.36	2.44
11	58	54.9	3.1	9.61	.18
12	24	28.6	4.6	21.16	.74
13	11	13.8	2.8	7.84	.57
14-18	2	8.6	6.6	43.56	5.07
					23.99

Degrees of freedom = 13

$\chi^2_{.975,13} = 24.7$

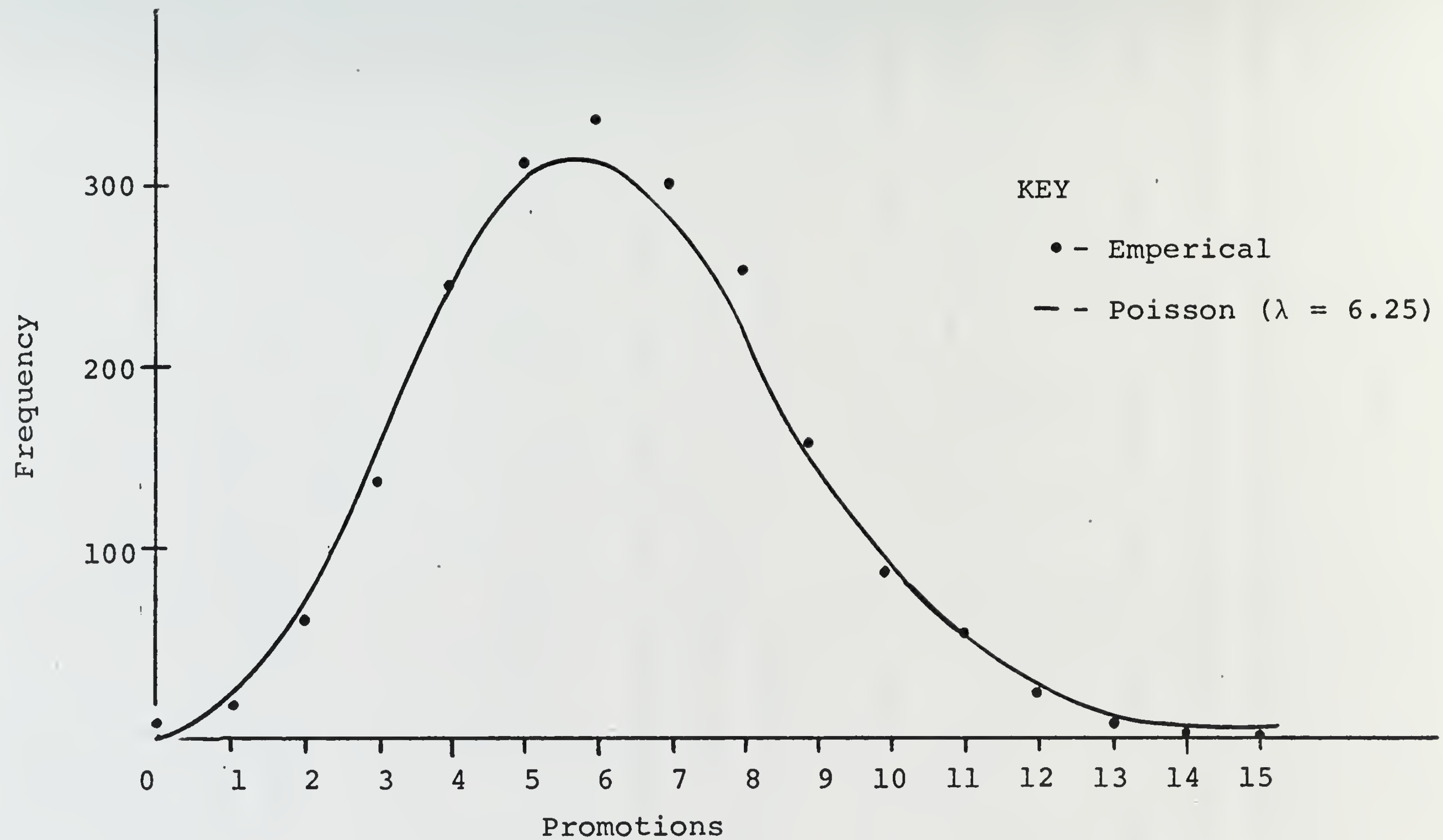


Figure 6. Frequency Distribution of Promotions When Promotions Occur Only After t Years In Grade.

IV. SUMMARY AND CONCLUSIONS

The problem we started out to solve was that of developing deterministic and probabilistic models of the senior Naval Officer ranks. The deterministic models established a feasible region for attrition and promotion rates with losses due only to "mandatory" retirements and with early retirements. The effect of early retirements was to produce a smaller feasible region of promotion and attrition rates.

The stochastic models investigated the effect of two different promotion policies; promotion only from those with minimum time in grade and a system with early promotion permitted.

In a personnel system with a fixed time until promotion, constant grade size and maximum time in the system, the distribution of inputs into the system was binomial. Since, with a binomial distribution determination of the parameters uniquely specifies the variance of the distribution, the variance in inputs can be obtained directly. Likewise, with promotions and retirements the variance can be obtained by determination of the distribution parameter.

If it is assumed that the models closely approximate the actual system the interdependence of the junior and senior ranks can be established. The next area of investigation would be to link the ranks together such that inputs into the senior rank would be promotions from the next junior rank which in turn, given a retirements distribution, would form an input distribution or promotion distribution from the third most senior rank.

In a personnel system in which the time until promotion is variable, in that promotion prior to minimum time in grade is permitted, a great deal of variability is introduced into both the distribution of inputs and retirements.

Although inaccessibility of data prevented direct verification of the models with the actual system, it is felt that these models could be used to gain insight into the Naval officer personnel system for the purpose of determining the effect of changes in promotion and retirement policy.

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13. ABSTRACT

This thesis develops deterministic and stochastic models for comparison of attrition and promotion rates for senior Naval Officers. The deterministic models show a feasible region for promotion and attrition rates. The stochastic models show the probability distribution of inputs into the grade and retirements from the grade which result from a promotion system based on a minimum time in rank and a promotion system where the number of promotions are determined independently of the number in rank.

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